The Impact of Non-Thermal Processes on Food Quality and Safety

by

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Outline

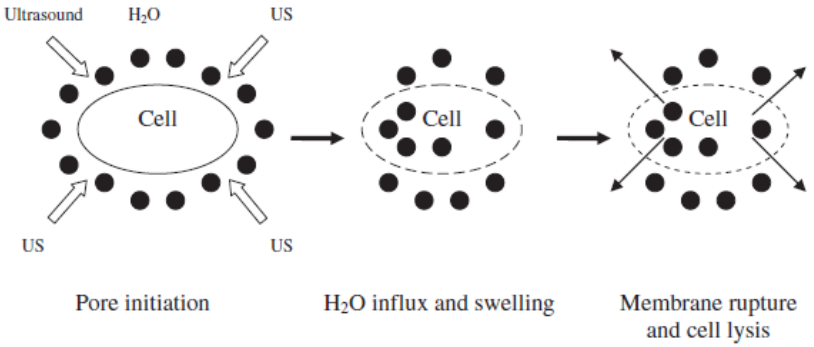
- Technologies and Principles
  - Ultrasonication (US)
  - Pulsed Ultraviolet light (PUV)
  - Antimicrobials
- Applications and Effects
- Future Implications

Introduction: Ultrasonication

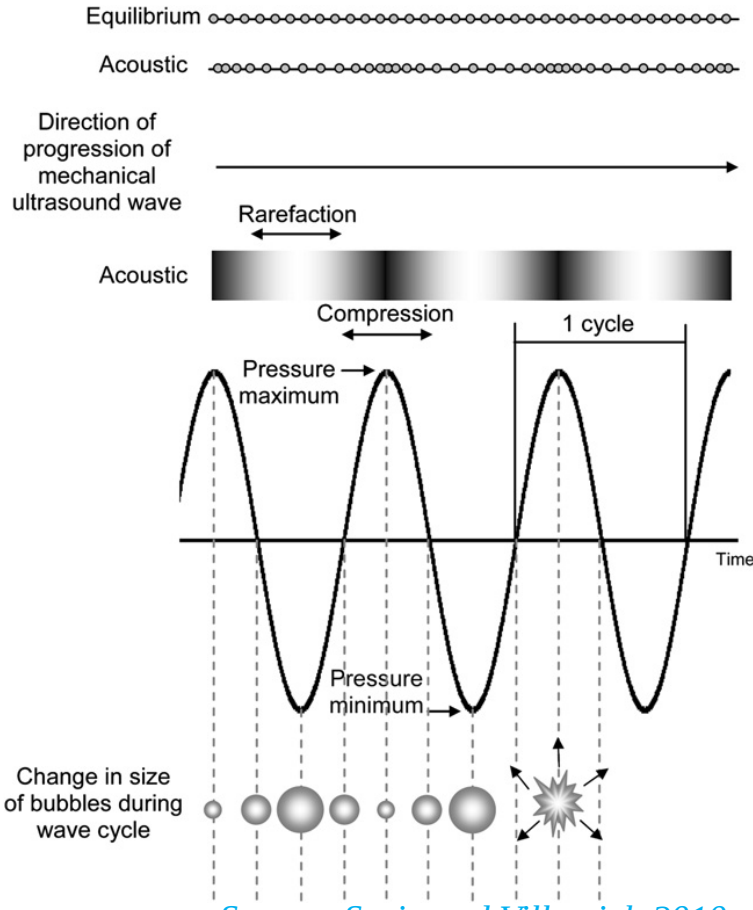
- Ultrasonication
  - Ultrasonic pressure wave directed to food surface
  - Generates force
  - if perpendicular
    - Results to compression waves
  - If parallel
    - Shearing waves
  - Both waves attenuate as they move through food
  - Depth of penetration and antimicrobial effect
    - Dependent on the frequency and intensity of waves
    - Composition of food

Introduction: Ultrasonication

- Ultrasonication
  - The rapid localized change in pressure
    - Cause shear disruption
    - Cavitation
      - Creation and rupture of microscopic bubbles
      - Thinning of cell membranes
      - localized heating
        - Lethal effect on microorganisms
        - Detachment of microbes in surfaces



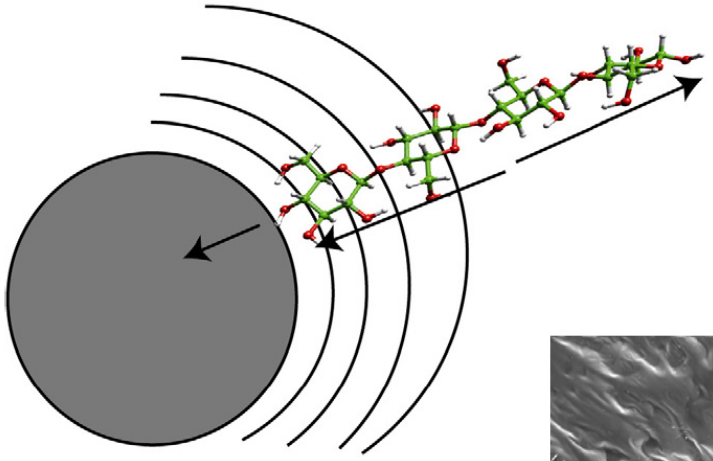
High pressure breaks cell wall
Disrupt cell membrane
Damage DNA

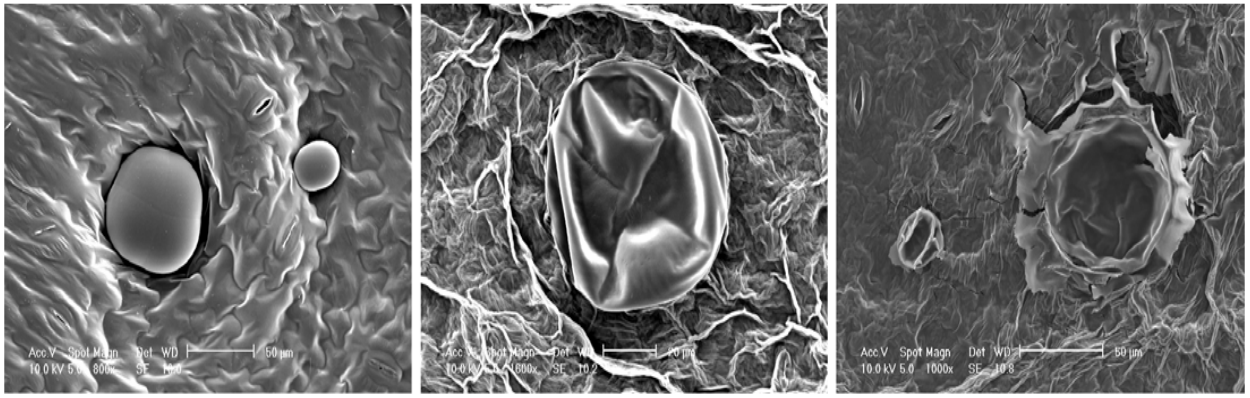


Source: Soria and Villamiel, 2010

Introduction: Ultrasonication

- Depolymerization effect on Cell Structure





Source: Chemat et al., 2011

Introduction: Ultrasonication

- Low Energy (< 1 W/cm²; >100 KHz)
  - Non-invasive detection
  - Stimulate activity of living cells
  - Surface cleaning
  - Effects on enzyme
  - Extraction
  - Crystallization
  - Emulsification
  - Filtration
  - Drying
  - Tenderization of meat

Introduction: Ultrasonication

- High Energy (>1 W/cm² (10 – 1000 W/cm²) ; Between 18 & 100 KHz)
  - Physical disruption,
  - Acceleration of chemical reaction
    - Degassing of liquid foods
    - Extraction of enzymes and proteins
    - Inactivation of enzymes
    - Induction of nucleation for crystallization
    - Enhance drying and filtration

Introduction: Ultrasonication

- Methods of US Applications
  - Ultrasonication
    - Low temperature
      - Inactivate enzymes and microbes
      - Heat liable products
      - Requires long treatment time
    -
  - Themosonication
    - Combination of untrasound and heat
      - Greater effects on microbes
      - Lower D and Z values than conventional thermal processing

Introduction: Ultrasonication

- Method and Applications
  - Manosonication
    - Combined sonication and pressure
      - Effectively inactivates microbes than ultrasound
      - Efficacy higher than ultrasound alone at the same temperature
  - Manothermosonication
    - Combination of heat, ultrasound and pressure
      - Much more effective than the three categories above
      - Inactivate enzyme/microbes at low temperature and short time
      - Heat stable enzymes also effectively destroyed
    - Effect on cavitation
      - Application of temperature and pressure maximizes cavitation
      - Heat resistant enzymes
        - Lipoxygenase, peroxydase ettc

Applications: Ultrasonication

- Different scales

500 L

50 L

1000 L

Source: Chemat et al., 2011

Ultrasonication: Enzymatic inactivation

❖ Inactivation of PME in tomato juices

Methods	°C	Volume (mL)	Intensity mg/L.min	D-Value (min)
Conventional	50	100	NA	25.3
Ultrasonication	50	200	0.007	241
	50	100	0.012	43
	50	50	0.020	24
Thermosonication	61	200	0.005	8
	61	100	0.007	2
	61		0.012	0.8
	72	200	0.004	0.7
	72	100	0.005	0.4
	72	50	0.008	0.3

Source: Raviyan et al., 2005

Ultrasonication: Effect on Quality

- The effect of ultrasonication on color and anthocyanin content in grape juices

Parameters	Before	After
pH	3.78	
Brix	7.02	
L*	22.06	22.69
a*	9.27	9.79
b*	-8.79	-7.97
Cyanidin-3-O-glucosides (CA) (mg/100 mL)	13.39	13.68

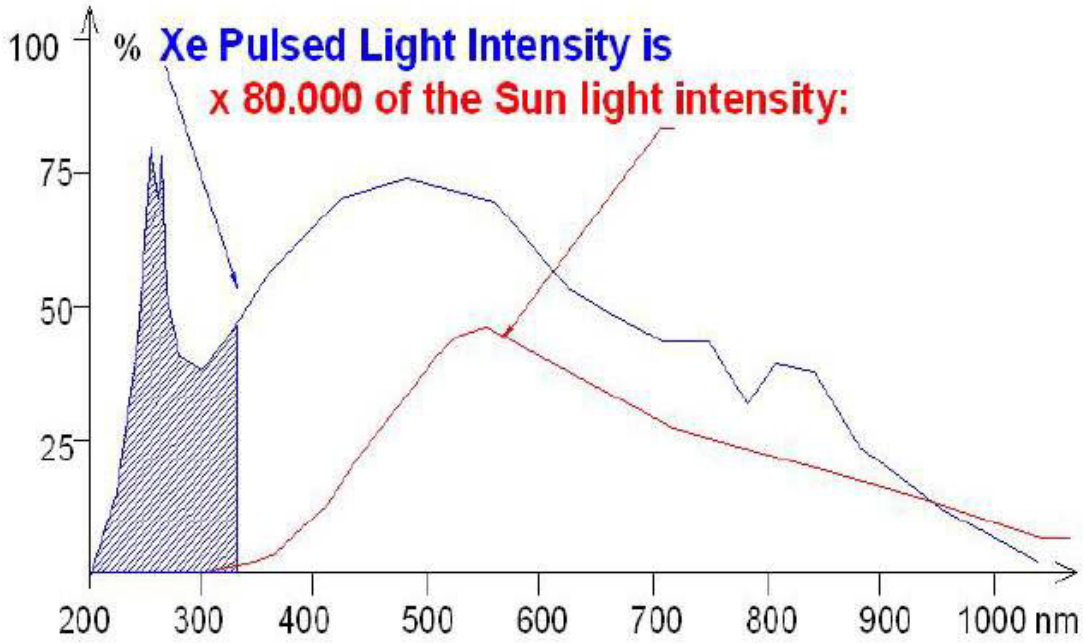
Source: Tiwari et al., 2010

Introduction: PUV

- Pulsed Ultraviolet light
  - Is a method of food preservation
  - Using intense and short duration of pulses of broad spectrum white light
  - The spectrum involves wavelength in the UV and near infrared region
    - Materials exposed to at least 1 pulse of light having an energy density in the range of 0.01 to 50 J/cm^2
  - Wavelength distribution
    - About 70% of the electromagnetic energy is within the range of 170 to 2600 nm used

Introduction: PUV

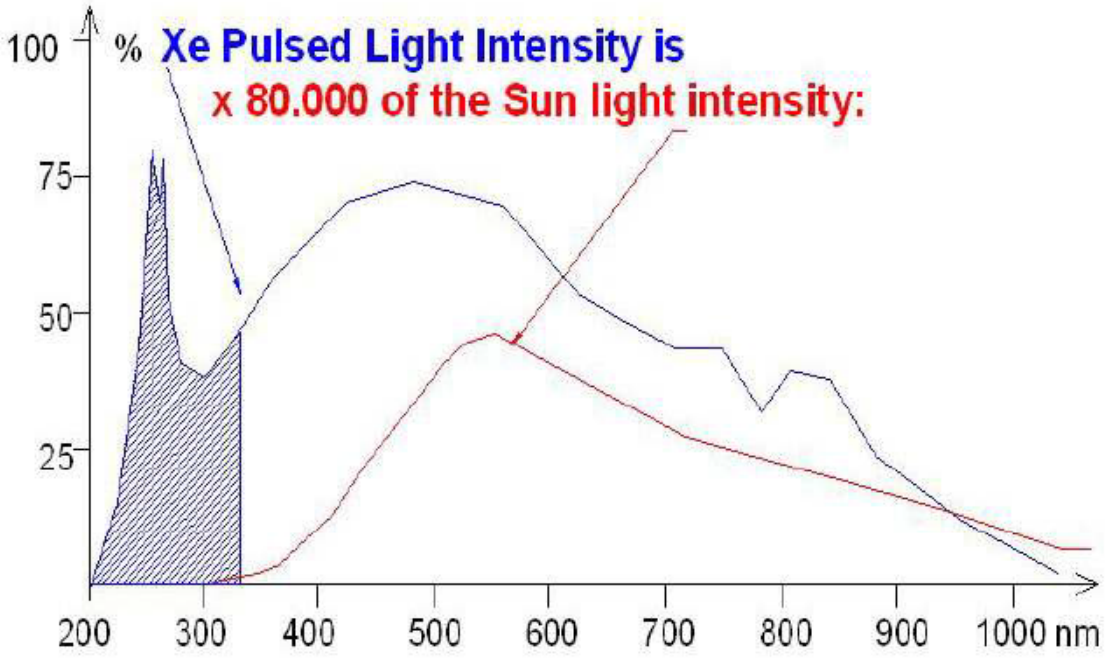
- Pulsed Ultraviolet light
  - Similar spectrum as sunlight
  - Emits electromagnetic radiation from 100 to 1100 nm
    - from the UV region to Infrared region
    - Peak emission between 400 to 500 nm
    - It is non-ionizing part of the electromagnetic spectrum

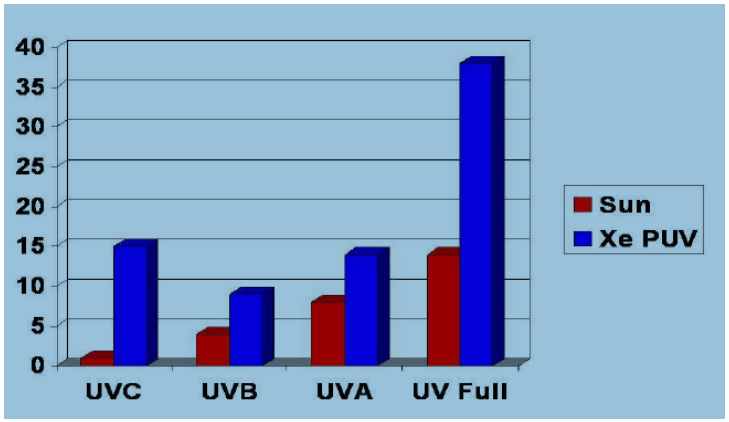


Source: http://steribeam.com/technology/SBS-PUV-principles

Introduction: PUV

- Pulsed Ultraviolet light
  - Short pulses (1 μs to 0.1 s)
  - Typically 1 – 20 flashes per second
    - Spectrum Intensity (Xenon produce about (80,000 x) at sea level





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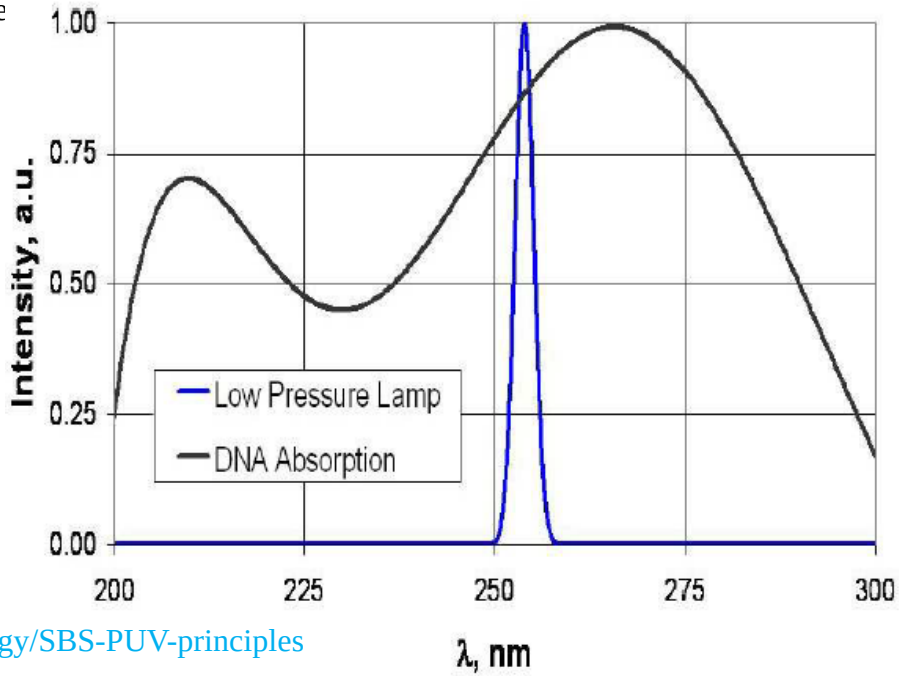
Introduction: PUV

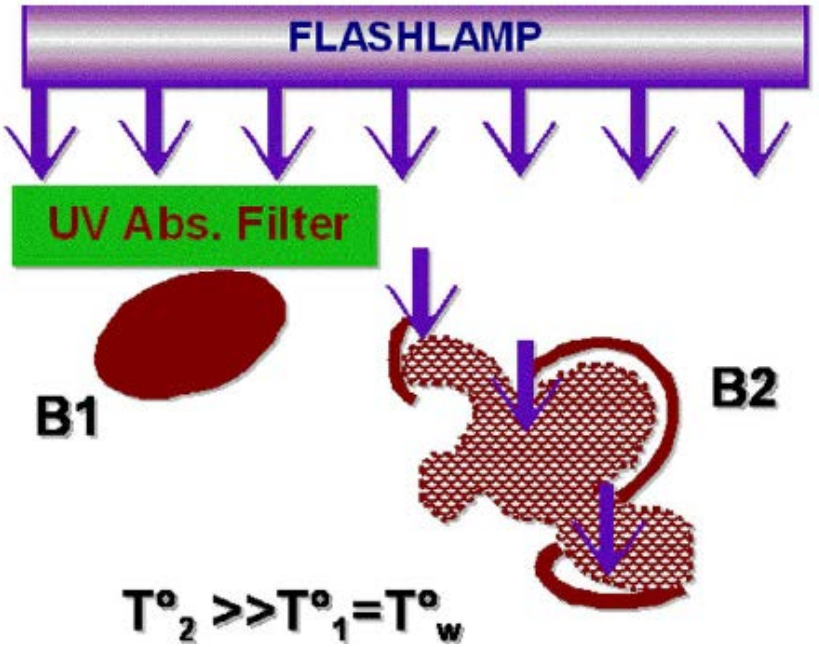
- Pulsed Ultraviolet light
  - Energy input to food surface or package surface area
    - Expresses in Energy per square area (J/cm²) or energy density
  - Broad spectrum of Pulse light inactivates microbes
    - Via the combination of photochemical and photothermal mechanism
    - Photochemical
      - Chemical modifications of proteins membrane and other cellular materials and DNAs
      - The UV-C provide greater photochemical effects



Source: http://steribeam.com/technology/SBS-PUV-principles

Introduction: PUV

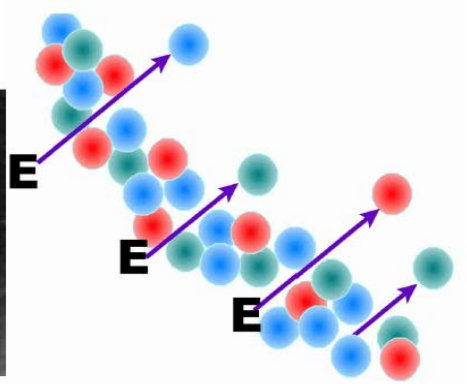
- Pulsed Ultraviolet light
  - Energy in the visual spectrum
    - Contributes to the photothermal effect
    - Large amount of energy is transferred rapid to the surface
    - Temperature increase
      - Sufficient to destroy vegetative cells

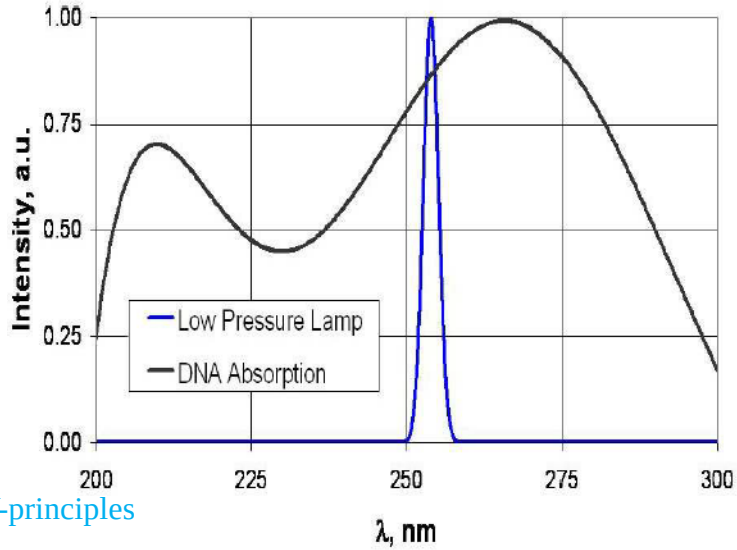


Source: http://steribeam.com/technology/SBS-PUV-principles

Introduction: PUV

- Pulsed Ultraviolet light
  - Wavelength is divided into different regions of
    - UA-A: 315 - 400
    - UV-B: 280 - 315
    - UV-C: 200 – 280
  - Microbial Effect
    - Absorption of energy by the conjugated double carbon bonds in proteins and nucleic acids
    - Cause crosslinking between the pyrimidine nucleoside bases in DNA
    - Disruption of cellular metabolism
    - Results of irreversible changes





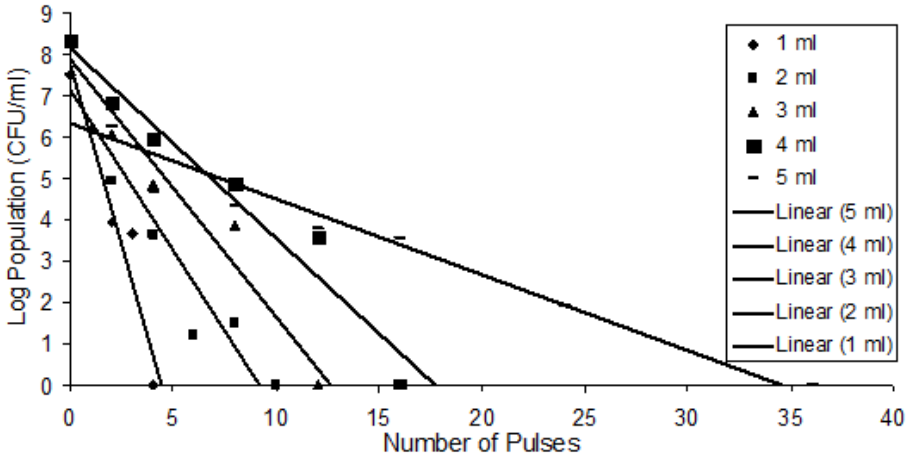
Source: http://steribeam.com/technology/SBS-PUV-principles

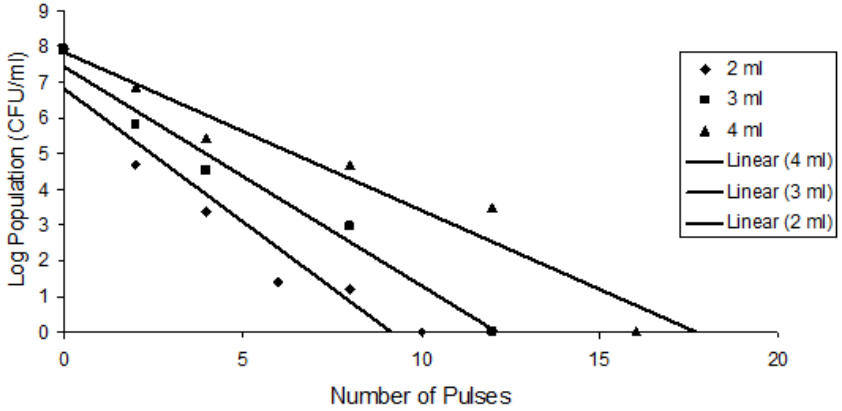
Application: PUV Systems

- Treatment chamber and generator
  - Static and or continues systems

Application: PUV Systems

- Effect on *Salmonella Enteritidis*

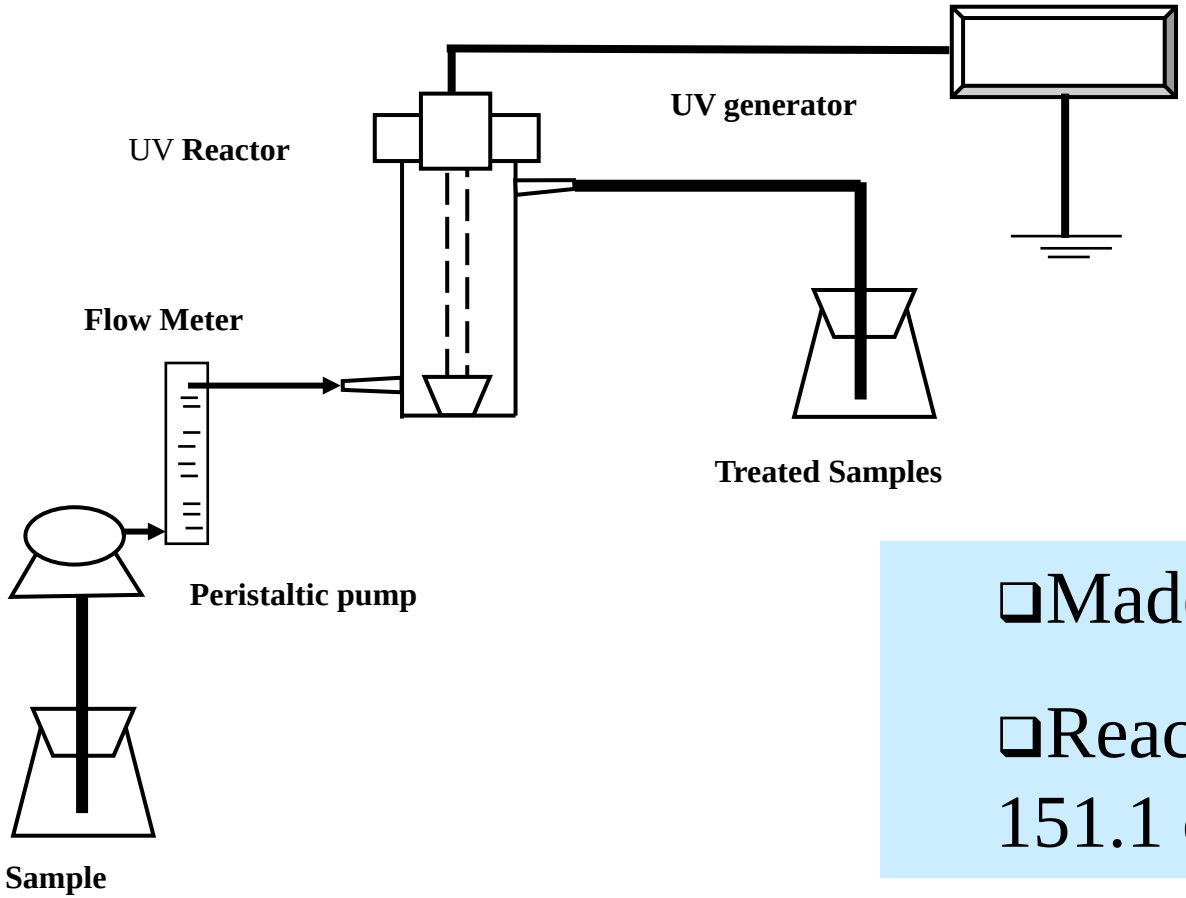




Source: Yang and Singh 2010

Application: PUV Systems

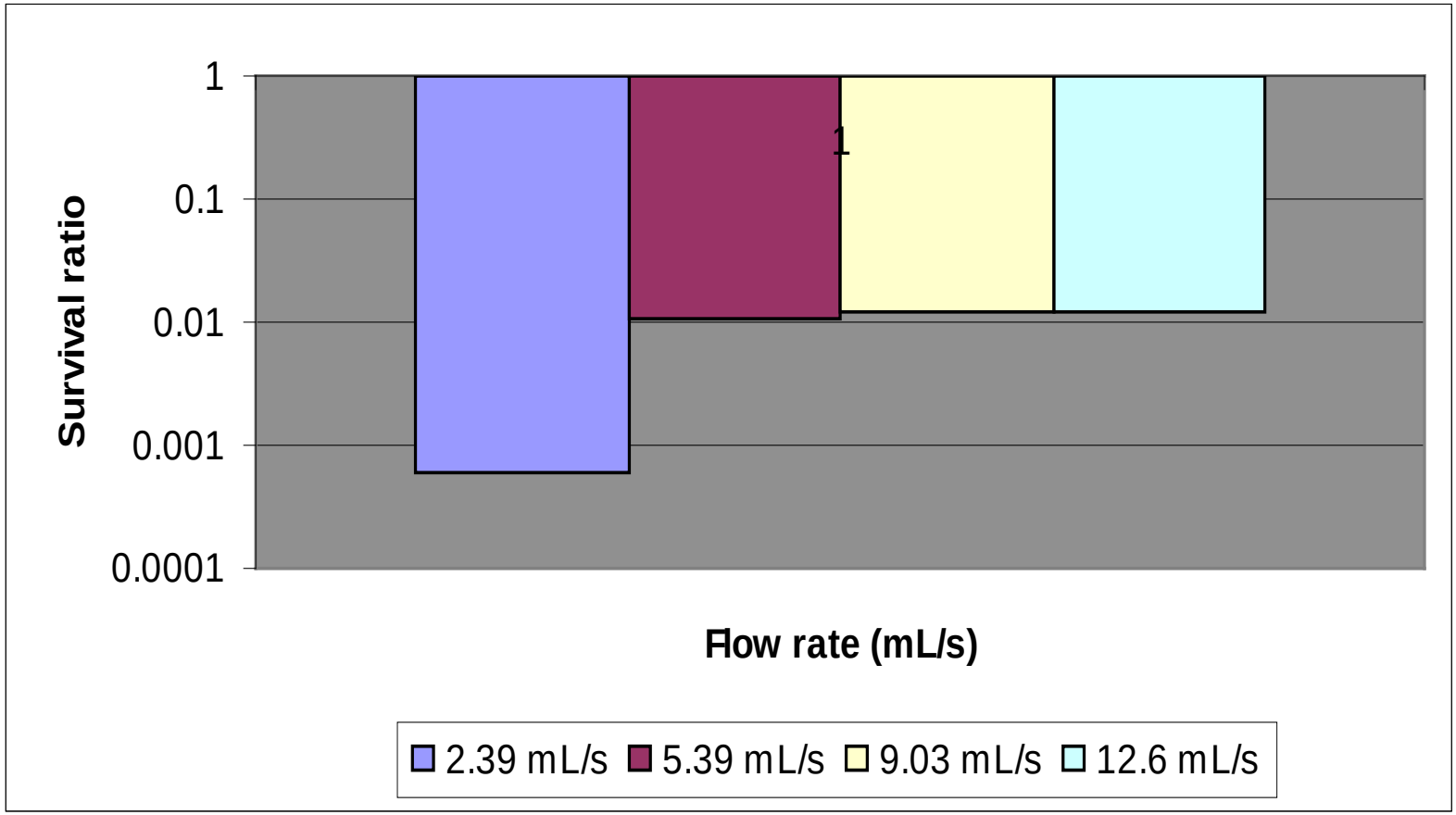
- Continuous UV Decontamination system for treating poultry chiller water



- Made of stainless steel
- Reactor Capacity = 151.1 cc

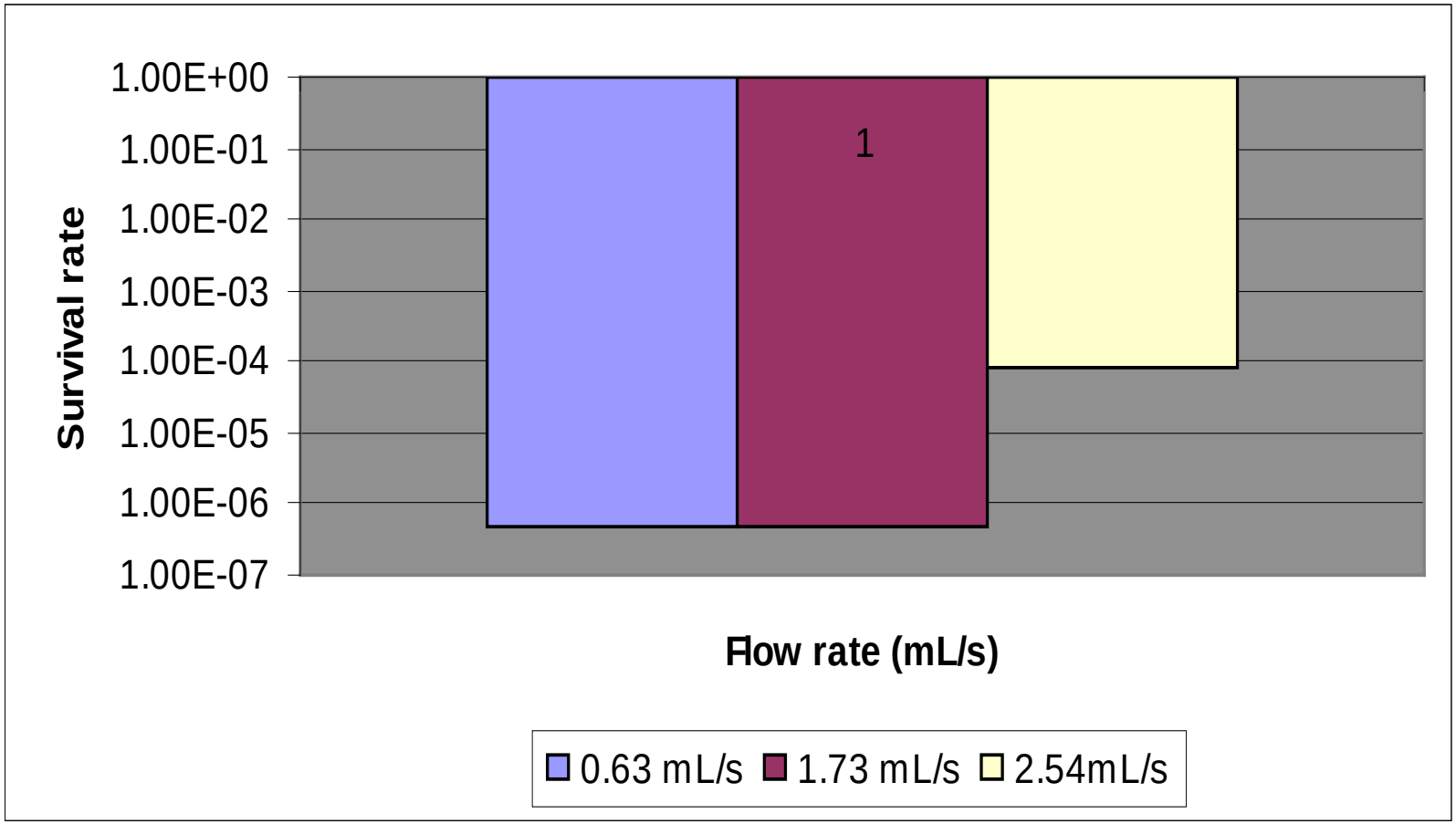
Application: PUV Systems

- Continuous reactor



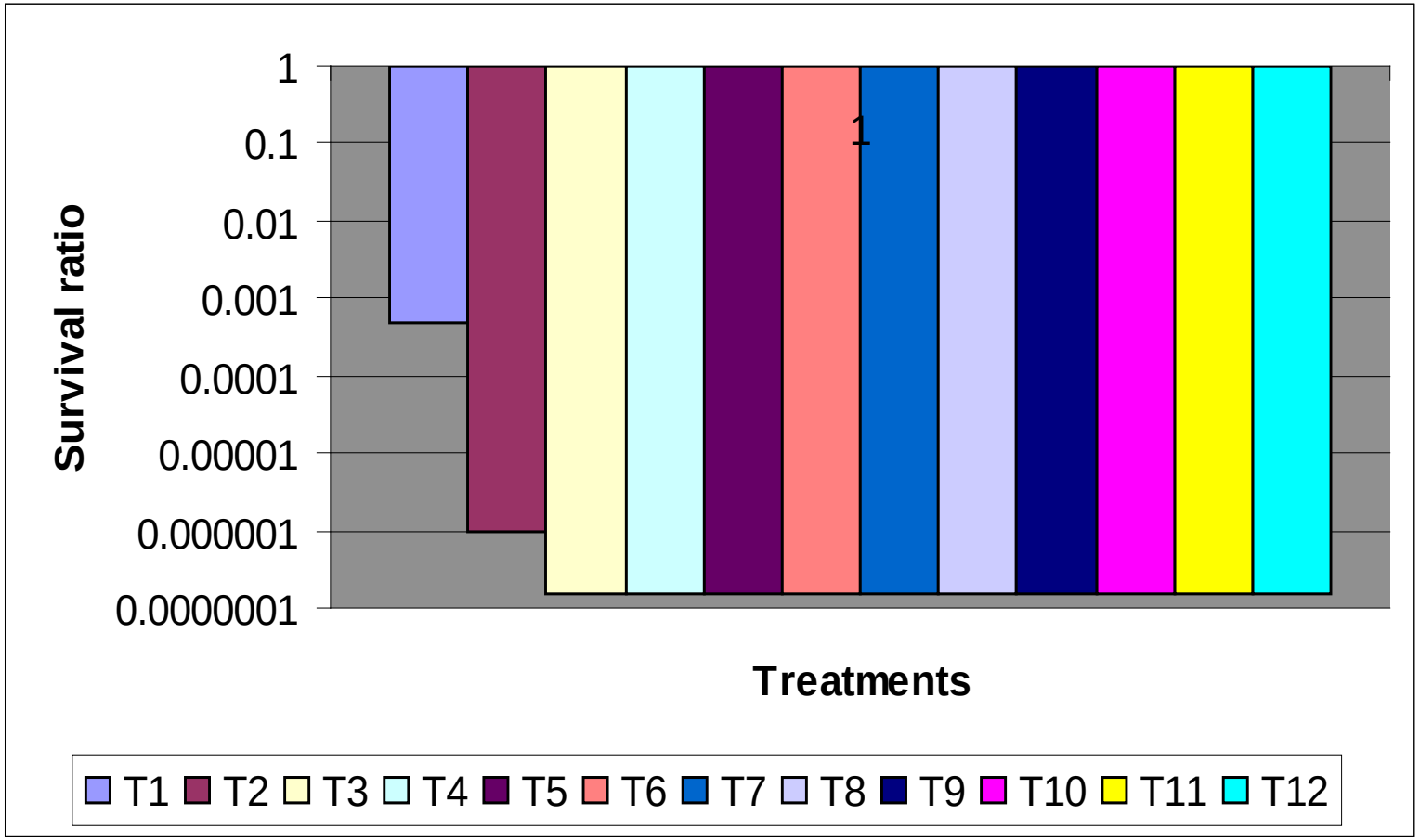
Application: PUV Systems

- Continuous reactor



Effect on Salmonella

- Pulsed UV effect on *Salmonella*



Introduction: Antimicrobials

- Crave for natural foods, organic and less chemically processed food are the trend
- Therefore, the application of Conventional aqueous Sanitizers for washing
  - Chlorine
  - Hydrogen peroxide
  - Trisodium phosphate
    - The use of this solution has not be successful in controlling
    - Produce adverse effect: chlorine --- trihallomethanes
- Use of Organic acids as antimicrobial
  - They are GRAS and known to inactivate foodborne pathogen

Introduction: Antimicrobials

- For example
  - Lactic Acid: are know to increase the lag phase of pathogens, lower the growth rate during storage
  - Lactic acid surface treatment: usually in water base solution and hydrophilic
- Challenges
  - Use of hydrophilic agent in hydrophobic environments
  - Many studies has shown microbes to be entrapped in fat matrix in meats and poultry
  - Thus limit the effectiveness of some antimicrobial
  - Surfactants (Sodium Lauryl sulfate)
    - Decrease surface tension and enhance wettability of hydrophobic surfaces
    - Amphiphilic, thus enhance mobility when mixed with antimicrobials

Applications: Antimicrobials

- Antimicrobial

Table: Organic acid antimicrobial effects in lettuces

Microbes	Trtm	Lactic Acid (Log CFU/g)		
	Con (%)	10 min	20 min	30 min
E. Coli	0.3	0.73	1.87	2.51
	0.7	1.26	1.92	3.09
	1.0	1.57	2.07	3.42
S. Typhimurium	0.3	0.72	1.46	2.08
	0.7	1.50	1.62	2.49
	1.0	1.76	2.06	2.67
L. Monocytogenes	0.3	0.70	1.71	2.52
	0.7	1.13	2.03	3.03
	1.0	1.20	2.14	3.45

Applications: Antimicrobials

- Effect of Essential oils on growth of E. coli ATCC 25922

Essential Oils	Concentration	Lag phase (h)	Growth rate (/h)
Lemon balm	20,000 ppm	5.21	0.4
Oregano	300 ppm	3.84	0.36
Rosemary	10,000	4.55	0.48
Oregano+Basil	1:2	11.28	0.45
Oregano+lemon balm	1:2	8.76	0.31
Oregano+Rosemary	1:2	5.84	0.38

Source: Gutierrez et al., 2008

Applications: Combine Ultrasound and OA

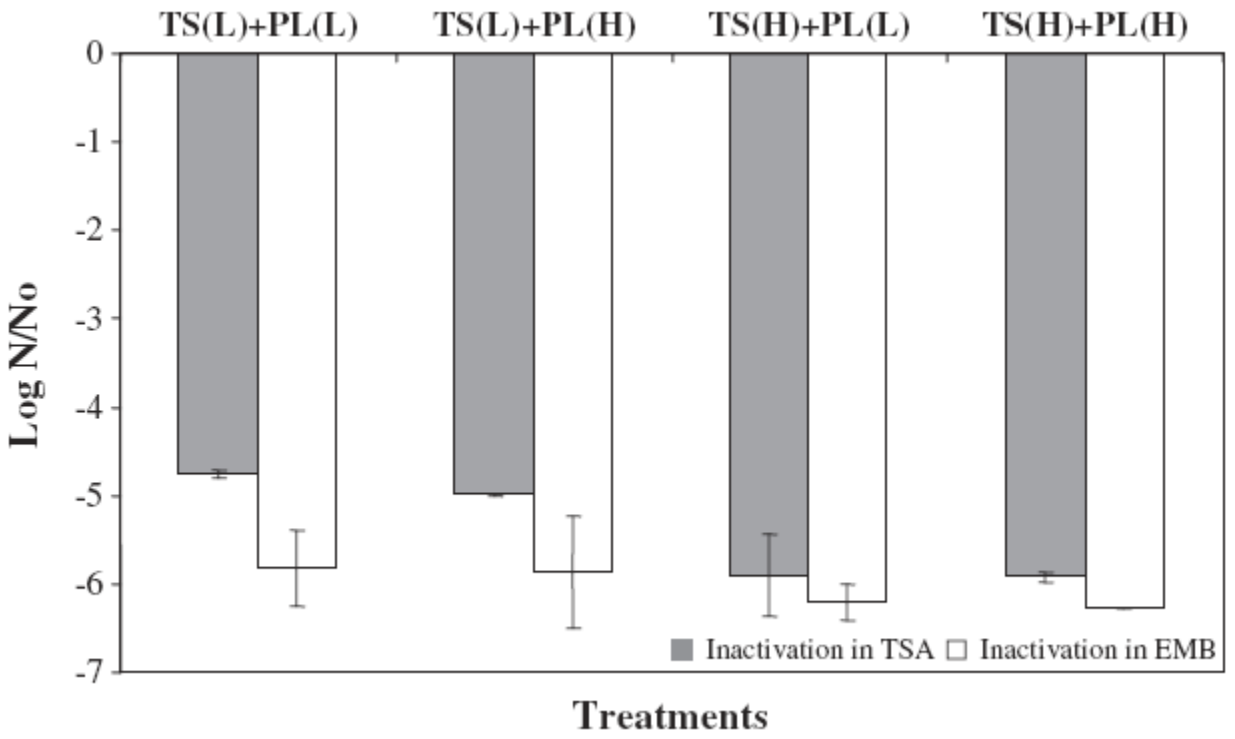
- Combine ultrasound and organic acid treatment of Escherichia coli O157:H7 in lettuce

Organic Acids	Concentration (%)	Log CFU/g	
		Organic Acid Treatments	Organic acid and Ultrasonic Treatments (40 Hz and 30 W/L)
	0.0	0.3^{a}	0.89^{a}
Malic acid	0.3	0.57^{ab}	1.09^{b}
	0.7	1.23^{bc}	1.78^{c}
	1.0	1.45^{d}	2.26^{d}
Lactic Acid	0.3	0.53^{a}	1.4^{ab}
	0.7	0.97^{ab}	2.21^{c}
	1.0	1.03^{bc}	2.53^{d}
Citric Acid	0.3	0.5^{a}	1.62^{b}
	0.7	0.91^{ab}	1.84^{c}
	0.1	1.15^{bc}	2.09^{d}

Source: Sagong et al., 2011

Applications: Combine Ultrasound and PUV

- Combine ultrasound and PUV inactivation E. coli O157:H7 in apple juice



Source: Munoz et al., 2012

Future Implications

- Potential in Food safety
  - Ultrasound
    - Enhance penetration to inaccessible sites (hydrophobic pockets in foods),
  - Combination of this technologies improve safety issues
    - Fresh cut fruit and vegetables; meat and poultry
  - Design of a suitable system
    - Combine PUV, Ultrasound and Acidification
    - Low cost and ‘Green technology’
    - Automated system in food production lines

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Thank you